Irrigation and Drainage

By

K. M. GURURAJA RAO.

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A I

"A river went out of Eden to water the garden."

—GENESIS, ii. 10

" the higher Nilus swells
The more it promises : as it ebbs, the seedsman
Upon the slime and ooze scatters his grain,
And shortly comes to harvest."

—ANTONY AND CLEOPATRA (SHAKESPEARE)

"A swamp at the mountain's base,
Pollutes all that has been gained ;
To drain dry this pestiferous place,
Is still the goal to be attained."

—GOETHE

Rs. 2/-

PRINCIPLES OF

IRRIGATION AND DRAINAGE

BY

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PREFACE

AFTER about twenty-five years of administration of large-scale irrigation-farming, I was posted in 1940, as Principal of the Mysore Agricultural School, Hebbal, Bangalore. I chose the subject: "Irrigation and Drainage", to teach to the students of the School. The notes prepared in that connection are published. In these days of specialisation it is the Irrigation and Drainage Engineer who must have the say in the matter. Though I am fully aware that the notes are not even a comprehensive summary on the subject, I humbly claim to present the subject from the crop-raising side, so that the principles of irrigation and drainage, in practical application, may be easy to understand. With progressive importance given by Governments to vast irrigation schemes, as the only means of preventing frequent crop-failures, the subject is fast becoming a major one in agricultural-expansion schemes. The correct and judicious use of irrigation water and proper drainage methods are largely, at present, absent—giving rise to wastage of valuable water and making good lands waterlogged and alkaline. I have hopes that these notes will be found useful not only to the students of agricultural institutions, but to the young men who will be forced on to irrigation-farming as a venture in the post-war period, when agriculture, it is expected, will be placed on a profitable footing.

July 1945.

K. M. GURURAJA RAO.

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IRRIGATION

CHAPTER I

DEFINITION AND HISTORY OF IRRIGATION

UNDER the term irrigation, as applied to agriculture, is included all operations or practices in artificially applying water to the soil for growing crops. It includes also, in a general sense, the conservation and storage of water-supply, the carrying of water from the source of supply to the irrigable area and distributing it to the lands. It may involve, in many cases, the development and bringing to the surface of water from underground sources by pumping or other means to lands which cannot be reached by gravity from the source of supply. It will thus be seen that a greater portion of the subject pertains to engineering and we are concerned, in the main, to methods of application of water to the land in relation to raising of crops.

Since successful raising of crops depends on sufficient water content of soil during periods of crop-growth, which cannot be depended upon, on rainfall alone, it would be easy to guess that irrigation should have been practised even before civilisation. It is said that the sunken island of Atlantis, opposite the present Gibraltar, shows an elaborate system of canals for irrigation, which takes irrigation-farming

so far back as 20,000 years. In the agricultural lyrics, Hesiod, who lived 3,000 years ago, refers to irrigation as having been practised long before his time by the Chinese people. 4,700 years ago a clever Egyptian ruler by name Menes, turned the course of the Nile upon the higher ground for irrigation purposes. 2084 B.C. shows Nile irrigation having been under systematic engineering. One of the oldest monuments at Thebes is said to contain a representation of a naked *fellah* (a farmer) drawing water from the Nile with well-swoop or shadoof resembling our *Yatha* or *piccota*. This is supposed to be about 5,000 years old.

Nearer home in Mysore, there is a case reported where irrigation was raised to a major issue culminating in national dispute. The Raja of Mysore had thrown an enormous dam across river Cauvery in about 1700, and thus diverted the waters of the river into his kingdom. The rice crops in Tanjore and Trichinopoly, which depended on these waters, dried which almost precipitated war between Tanjore and Madura against Mysore, but for timely rains and the river Cauvery coming down with unusual violence and sweeping away the dam.

Importance of Irrigation and Advantages Conferred by it on Agriculture

Importance for irrigation arises from lack or failure of rainfall at the time required by crops. In

some regions as in Malnad though the annual precipitation is adequate for growing crops, it frequently happens that rainfalls at times when it is not required by crops and fails at times when it is most needed, thus making irrigation necessary. In the dry districts of Kolar, Tumkur and Chitaldrug, irrigation assumes a very important role in assuring crop-yields. Irrigation, it should be said, is one of the most important means of raising agriculture to scientific accuracy and magnitude, as it supplies moisture to the soil at proper times and in the exact quantity required.

For British India, on the whole, 18% of the nett area cultivated is irrigated from Government system of irrigation, that is, out of 340 million acres under cultivation, 63 million acres command irrigation. In Mysore it is about 22%.

The following statement gives the percentage of area irrigated to cropped area in the several provinces:—

Madras	19·3
Bombay Deccan	4·0
Sind	86·0
Bengal	2·0
United Provinces	10·7
The Punjab	59·0
Bihar and Orissa	2·9
Central Provinces	1·9
N.W.F. Province	50·0

The following statement gives the area of catchment basins of important rivers in the Mysore State,

and the percentage of area brought under the tank system:—

Name of river	Total area under catchment in sq. miles	Percentage area under tank system
Tungabhadra	11,696	56·47
Palar	1,115	100·00
N. Pennar	2,628	85·35
S. Pennar	1,424	85·8
Cauvery	11,340	51·75

Of the total area of the State, 29,455 sq. miles 60% of the catchment area has been brought under the tank system, probably the highest in India.

Irrigation farming raises agriculture to a dependable occupation as otherwise, with only rainfall as a source of water-supply, it becomes a gamble. Irrigation is a blessing as it brings to humanity conditions which assures crop-production, converts extensive cultivation into intensive one, with better homes and more homes, with greater comfort, more profit from crops and the incidental raising of the standard of living. An example of this is seen in the Mandya District under the Krishnaraja Sagara irrigation scheme.

Soil in Relation to Irrigation

Soil as a medium for growing crops, is too well known. It appears to be static but is intensely dynamic. The roots of plants, that penetrate the soil in search of food, soil water or the aqueous solution from which plants draw all their food, except carbon dioxide which is absorbed by its aerial portions, the soil

atmosphere, the biological processes (about which little is known) not to speak of mechanical movements in the soil due to wind, rain, moving water and cultural operations, make the soil condition very dynamic.

Plants, it is known, take their food in a state of solution and the water of irrigation is the one factor, during rainless period, that influences plant life.

The water in the soil is held in three ways:—

1. Hygroscopic,
2. Capillary, and
3. Free or gravitational water (Fig. 1).

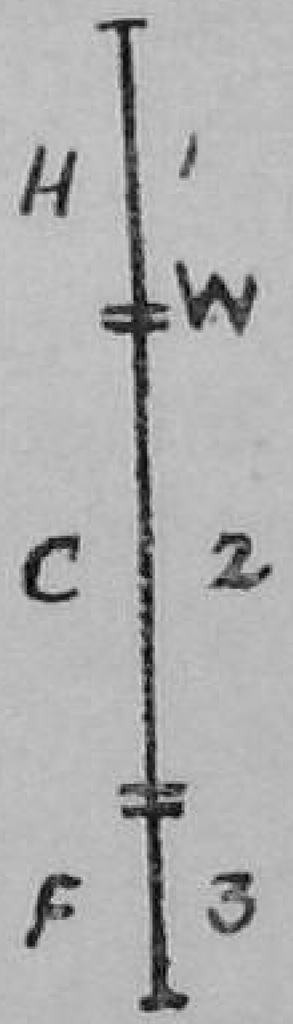

FIG. 1. The line shows proportional amounts of three forms of soil moisture:—

1. Represents the portion of the hygroscopic moisture (H), in the soil in dry state which is not available to plants. W marks the wilting point, the portion below which is 2.
2. Portion of capillary moisture in the soil (C) available to plants. This water moves from wet to dry portions of soil against gravity.
3. Free or gravitational water (F) in saturated soil. It is injurious to plant life, and so has to be removed by drainage.

1. Hygroscopic moisture is water that is in too close proximity with soil grains to be useful to plant life. It can be got rid of only by applying heat to the soil, and on cooling, readily absorbs it from air. Soils, which are apparently dry, contain this moisture in quantity depending upon porosity of soil, temperature and humidity of the surrounding atmosphere.

2. Capillary or film water is the water that clings to soil particles or aggregates as a thin film. It surrounds each or cluster of particles or aggregates and is held by surface-tension against gravity. It is this that helps capillary water to move in the soil from wet to dry part of the soil. Arrangement of soil grains, their size and thickness of film fixes the amount of this water. Proper time to work the soil is the time when capillary water is just right, when best structural conditions prevail in the soil.

3. *Gravitational water.*—This water is the free water that moves under the law of gravity. Water in excess of capillary capacity of a soil lies in the soil-pores working its way downwards. It is this water that gives rise to waterlogged condition in a soil and forms the subject of soil drainage, as it inhibits soil aeration and is harmful to plant life.

The first, *i.e.*, hygroscopic moisture plays no part in plant life. It is the second and third that play an important part in agriculture.

When a small quantity of water is added to an absolutely dry soil, there is, to begin with, a slight

shrinkage in soil volume. The water spreads in a thin film over the surface of solid soil particles. With further addition of water the apparent volume of the soil increases until a maximum is reached. What is known as the "optimum water content" of the soil corresponds to this critical content. Beyond this optimum stage, if further water is added, is the stage at which is found, what is known as "free water", accompanied by important changes in soil structure. With continued addition of water, apparent volume decreases rapidly tending to soil aggregates breaking down and the "crumb" structure of the soil, which is desired most by the agriculturist, is lost and the phenomenon known as "Puddling" is produced. This last stage is not desired by the agriculturist, though the potter and the bricklayer like it.

Porosity or porespace of a soil depends on size and gradation of individual soil particles, known as "texture" of the soil, and the manner they are arranged in groups or clusters, known as "structure".

The following statement gives percentage of porespace and surface area in different soils under ideal arrangement of spherical soil particles:—

Soil		Effective size of soil grains in millimetres	Percentage of porespace	Surface area of 1 c.ft. of soil grains in square feet
Finest clay soil	..	0·004956	52·94	173,300
Clay soil	..	0·008612	48·00	110,500
Heavy red clay	..	0·01111	44·15	91,960
Loamy clay	..	0·02542	49·19	70,500
Clayey loam	..	0·01810	47·10	53,490
Loam	..	0·02197	44·15	46,510
Sandy loam	..	0·03035	38·83	36,880
Sandy soil	..	0·07555	34·45	15,870
Coarse sand	..	0·1432	34·91	8,381

(*After King*)

A theoretical ideal arrangement of round grains and corresponding effect on the porespace is shown in the diagram taken from Ayers and Scoates (Fig. 2).

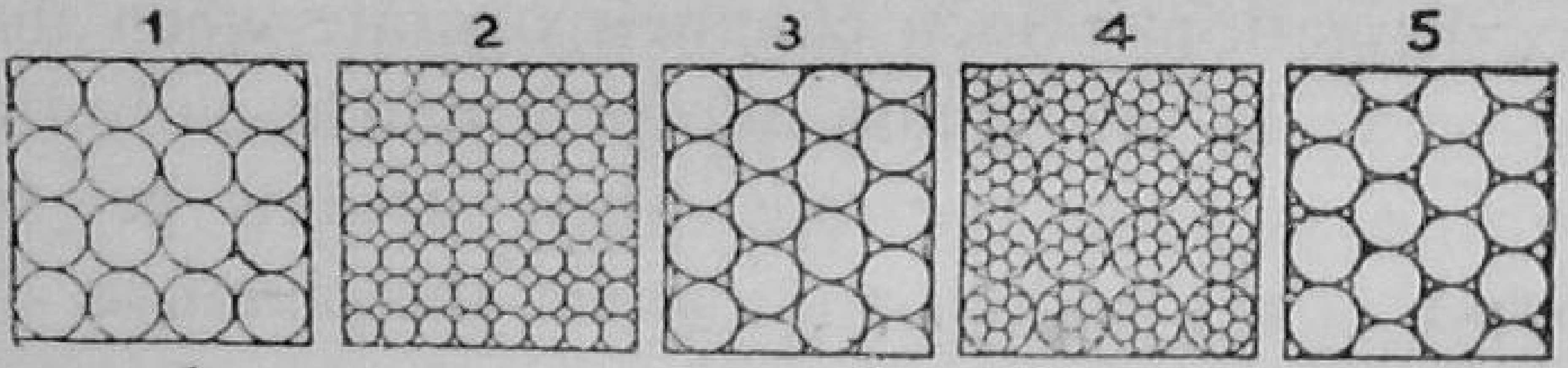

FIG. 2. Showing ideal arrangement of spherical soil particles.
1 and 2. Columnar order, 47·6 per cent. of porespace.
3. Oblique order, 25·95 per cent. of porespace.
4. Compound spheres in oblique order, 75 per cent. of porespace.
5. Three sizes of spheres with closest packing about 5 per cent. of porespace.

(*After Ayers and Scoates*)

A study of the diagram will explain why a clay soil contains 65% more porespace than a sandy soil and consequently gives a theoretical reason for a practical fact as to why water will pass through more freely in sandy soil than it will through clay.

CHAPTER II

SOURCES OF WATER FOR IRRIGATION

THE following are usual sources of water for irrigation:—

(1) Perennial streams,
(2) From floods of rivers held in big reservoirs,
(3) Tanks,
(4) From natural storage in the ground being recovered from wells sunk in the ground.

(1) *Perennial streams.*—Water for irrigation from the streams are taken through diversion channels at higher reaches, to flow to reach lands lower down for irrigation. Such channels operate when the head of water in the stream allows it and usually function during monsoon periods when streams get freshes. Most of the paddy lands under the channels of river Hemavathi and Cauvery are of this type. They function from about the middle of June to December.

(2) *From floods of rivers held in reservoirs.*—These may be termed big tanks as the principle is similar. Since such reservoirs are constructed to impound large quantities of water of big rivers the dams are of masonry. The first such dam in Mysore was built in Boranakanive, in Chiknayakanahalli taluk, of Tumkur District. Next was Vanivilasa Sagara across river Vedavathi (Mari Kanive) in Hiriyur taluk of Chitaldrug District, and the last

and biggest is Krishnaraja Sagara near Mysore across river Cauvery. They irrigate 3,000, 10,000 and 120,000 acres respectively. There are others also like Bhadra, etc. The K. R. Sagar is the third largest in the world. The first largest is in Sudan and second is the Assouvan dam in Egypt.

(3) *Tanks.*—These are usually earthen dams thrown across valleys to collect natural drainage which would otherwise flow into rivers. The Deccan, South India and Mysore are the home of tanks. The construction of these tanks is so highly developed that it would be difficult to find a valley which has not been thus exploited for irrigation purposes. It is very common to see a series of tanks one below the other, in valleys, the surplus waters of the above feeding the one below it. The valleys of Pennar and Palar are good examples of this.

(4) *From natural storage in ground water, being recovered from wells sunk in the ground.*—Wells are holes dug in the ground to a depth where water in sufficient quantities is recovered from the underground storage. There is no reliable known data to guide us for selecting sites for successful well-sinking. Water-diviners and other agencies, including *mantrams* and astrological methods are fully in vogue, but there is found everywhere, except in lands with sandy subsoil near banks of streams, as near Palar and Pennar rivers, an element of chance for a successful well. It is not rare to find two wells within a hundred

yards of each other, one with abundant water-supply and the other with no water.

Bore-wells are, of late, playing an important part but so far, for irrigation purposes, they are not yet much in evidence. From reports, we learn much headway has been made, in this line, in other countries especially in Australia where bore-wells as deep as 5,046 feet have been sunk. A case of a well 1,663 feet deep, where water rose to the surface and flowed at the rate of 300,000 gallons a day is reported. Such wells come under artesian or sub-artesian types.

There are sources of irrigation water in Madhugiri and Koratagere taluks which are known locally as *Thalaparages* (ತಲಪರಿಗೆ). They are similar to sub-artesian springs, which are guided in shallow channels to irrigate lands lower down. These are confined to areas in Madhugiri and Koratagere taluks which are interspersed with streams with sandy beds and the subsoil generally is porous, allowing sub-surface flow of water.

The area irrigated by tanks, wells and channels for Mysore State is shown in the following statement. The relative importance of these systems may be seen from the following table:—

1937–38

District		Area irrigated by Government channels	Area irrigated by tanks	Area irrigated by wells
Bangalore	..	1,659	60,650	18,528
Kolar	..	3,280	90,184	26,189
Tumkur	..	3,993	71,755	16,038
Mysore	..	136,183	36,401	..
Hassan	..	15,100	79,945	..
Shimoga	..	13,052	163,750	1,989
Kadur	..	9,042	36,785	..
Chitaldrug	..	10,500	35,756	23,500

It will be seen that the dry districts of Kolar and Chitaldrug have the largest area under well irrigation.

It is estimated that, roughly for the whole of India, of the total rainfall, 6% is used for irrigation purposes, 35% flows into the sea and the rest is absorbed by the soil, used by plants or evaporates.

CHAPTER III

DUTY OF WATER

It is usual to talk of quantity of water required for raising crops to maturity in terms of " Duty of Water ". Briefly the term " Duty of Water " is a form of expression for the quantity of water required for irrigation to bring a crop to maturity, the period of irrigation which the crop requires for full maturity being known as the " Base ". It is expressed as the area which a continuous flow of water—usually known as ' Cusec ', that is, one cubic foot of flow per second—known in America as second foot—of a given quantity will irrigate in bringing a crop to maturity. Miner's inch is another term of measure of water which varies from 1/40 to 1/50 of a cusec.

There are two methods of expressing Duty of Water :—

(1) *Gross duty of water.*—This represents the area commanded by the flow of water as measured at the source of supply, that is, at the canal-head or tank-sluice. It includes wastage in channels through evaporation, seepage and other losses on the way, in addition to what is used for maturing crops.

(2) *Nett duty of water.*—This represents the area commanded by water delivered at the field. This includes water that is used for plant-growth and losses due to evaporation, percolation and waste in the field due to wrong systems of irrigation or neglect.

The difference between (1) and (2) gives efficiency of canals and distributaries.

It is difficult to fix the duty of water as it depends on the kind of crop, character of soil, rate of evaporation in the locality and the method and skill of the person using the water. When water is applied to the soil, a part evaporates, a part is carried downwards beyond the root zone and a portion is made use of by growing plants. It is estimated that it requires from 300 to 500 pounds of water to produce one pound of dry vegetable matter. The amount of water required, roughly, for irrigation over a season according to the best data, varies from 2 to 4 acre-feet. The lowest duty of water is found under tanks where due to neglect it may be as low as 20. The highest may reach 250 under lift irrigation. It is reported in California under high efficiency and for orchard irrigation the duty is as high as 500.

The following simple rules and equivalents on the subject may be given:—

(1) A cusec, which term is used to express a flow of one cubic foot per second, is equal to 375 gallons a minute.

(2) 22,687·5 Gallons of water, or in cubic feet 3,630 will cover one acre one inch deep : an acre inch.

(3) 225 Gallons a minute will cover one acre one inch deep in one hour and forty minutes.

(4) To measure flowing water in canals multiply the area by the mean velocity of its flow in feet per second which gives volume in cubic feet.

(5) One cusec, roughly, is equal to one acre inch of water per hour. One cusec per day is roughly 1·98 acre feet.

(6) One acre foot is equal to 2,72,250 gallons.

(7) 2 to 5 acre inches are required for each irrigation over an acre depending on the soil and crop. 60 to 90 thousand gallons of water are required for sugarcane per irrigation on heavy soil.

(8) Doubling the diameter of a pipe increases its capacity four times.

(9) One cubic foot of fresh-water weighs 62·5 pounds and contains 6·25 gallons.

Quality of Water of Irrigation

It may be noted, in passing, that a knowledge of the nature of water used for irrigation is desirable. Water in its flow dissolves and carries with it some of the mineral and alkali salts. Some are harmless, while others are highly injurious to plant growth. There is no hard and fast rule laying down the amount of soluble salts or alkali in water that will render water unsafe for irrigation purposes. This will depend on the nature of the salts, condition of the soil, amount of water used and efficiency of drainage by which surplus water is carried away, so as to prevent alkali formation within the plant rootzone. Roughly it may be said that one-tenth of one per cent. of soluble salts or 100 parts of salt in 100,000 of water is the limit of safety for irrigation waters.

CHAPTER IV

WATER-LIFTS

THESE are contrivances to lift water from a lower level to a higher level so that water may flow on to the field for irrigation.

Three kinds of power are used for this purpose :—

1. Human power,
2. Animal power and
3. Mechanical power.

HUMAN POWER LIFTS

Piccota or Yatha (ಯಾತ) (Fig. 3)

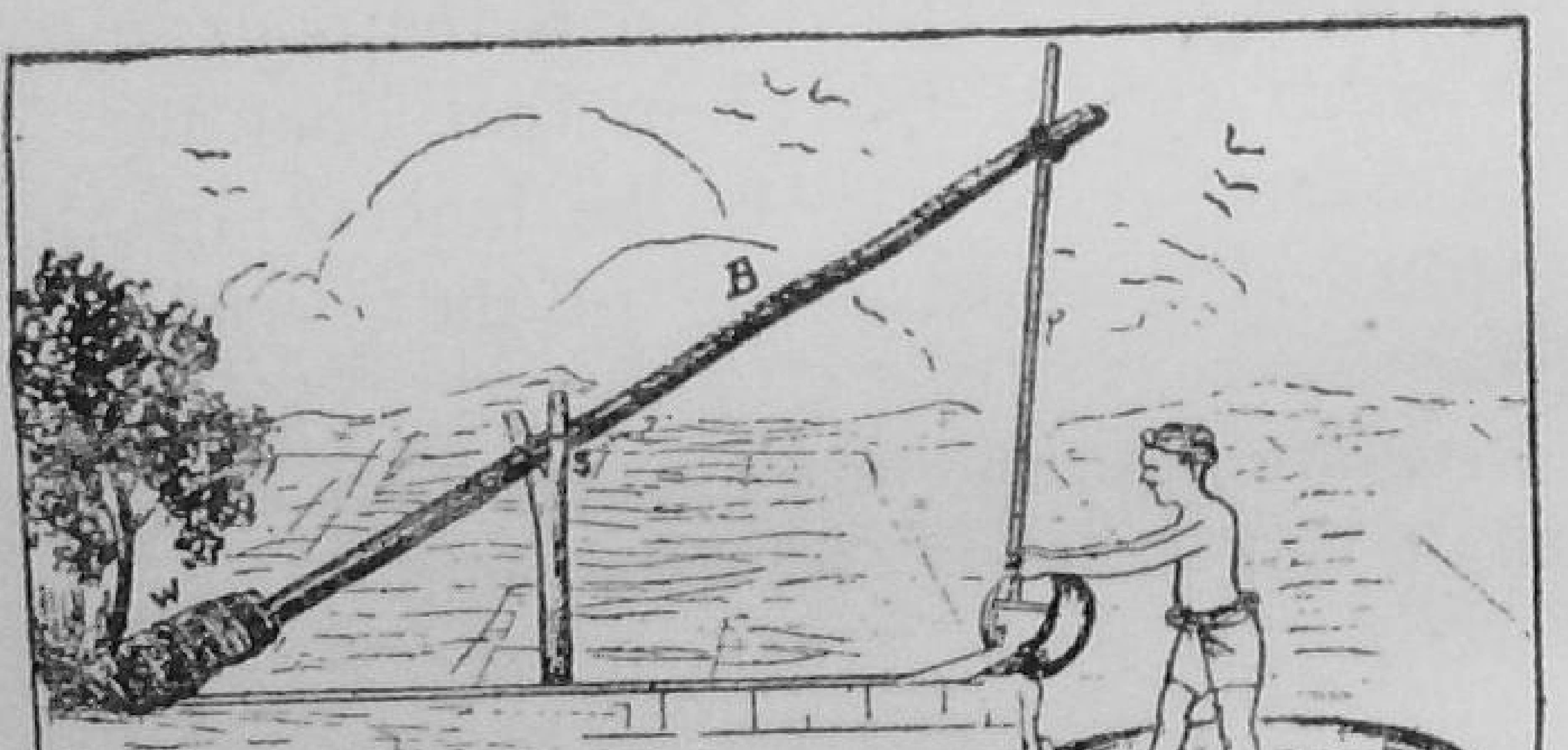

FIG. 3. *Piccota* or *Yatha*

B. Beam to which the bucket pole (P) is attached.
S. Pin on which the beam moves.
W. Counter-weight at the small end of the beam.

The most common, efficient and at the same time simple in construction among the first is the *piccota*. It is useful for lifting water up to 15 feet. It works on the simple lever principle. It consists of a long beam poised on a pin, at the long end of which is the bucket attached to a pole, and at the other short end, there is a weight of stone and mud, slightly more in weight than the bucket when filled with water. The man, when sending down into the well the empty bucket, uses his weight and strength, but as soon as the bucket is filled the counter-weight at the other end of the beam is made to operate, the man merely guiding the bucket-pole moving upward until it reaches the platform on to which the bucket is emptied with some skill. As it is the counter-weight at the short end of the beam that does the lifting the mechanical efficiency is the highest among the water-lifts. The construction of the *piccota* is very simple.

Depending on the depth of the well, each bucket delivers 6 to 8 gallons. Where men move as counter-weights on the beam 12,000 to 15,000 gallons can be raised per hour.

Swing-Basket or Gude (ಗೂಡೆ) (Fig. 4)

For low lifts of three to four feet swing-basket is used. This consists of a basket with two sets of ropes on each side, which are used by two men, who stand facing each other. The basket is swung to fill

in water and is raised and discharged on to the platform. The work of swinging the basket up is done not by the use of strength, as it looks, but by the play of the back muscles which are used to throw

FIG. 4. Swing-Basket or *Gude*

the weight of the men against the ropes to lift the basket. The capacity of the basket is about 2–3 gallons and about 1,200 to 1,500 baskets can be discharged per hour.

Archimedian Screw

Another low lift, the Archimedian Screw, may be mentioned. It consists of a cylinder, one end of

which dips into the water. Within the cylinder there is a spiral partition, which as the cylinder turns gradually, screws up the water. This works very efficiently for very low lifts but is not common.

Animal Power Lifts

Mhote or Kapile [Figs. 5 (*a*) and (*b*)]

Of the water-lifts where animal power is used *Mhote* or *Kapile* takes the pride of place for simplicity of construction, mechanical efficiency, and as the

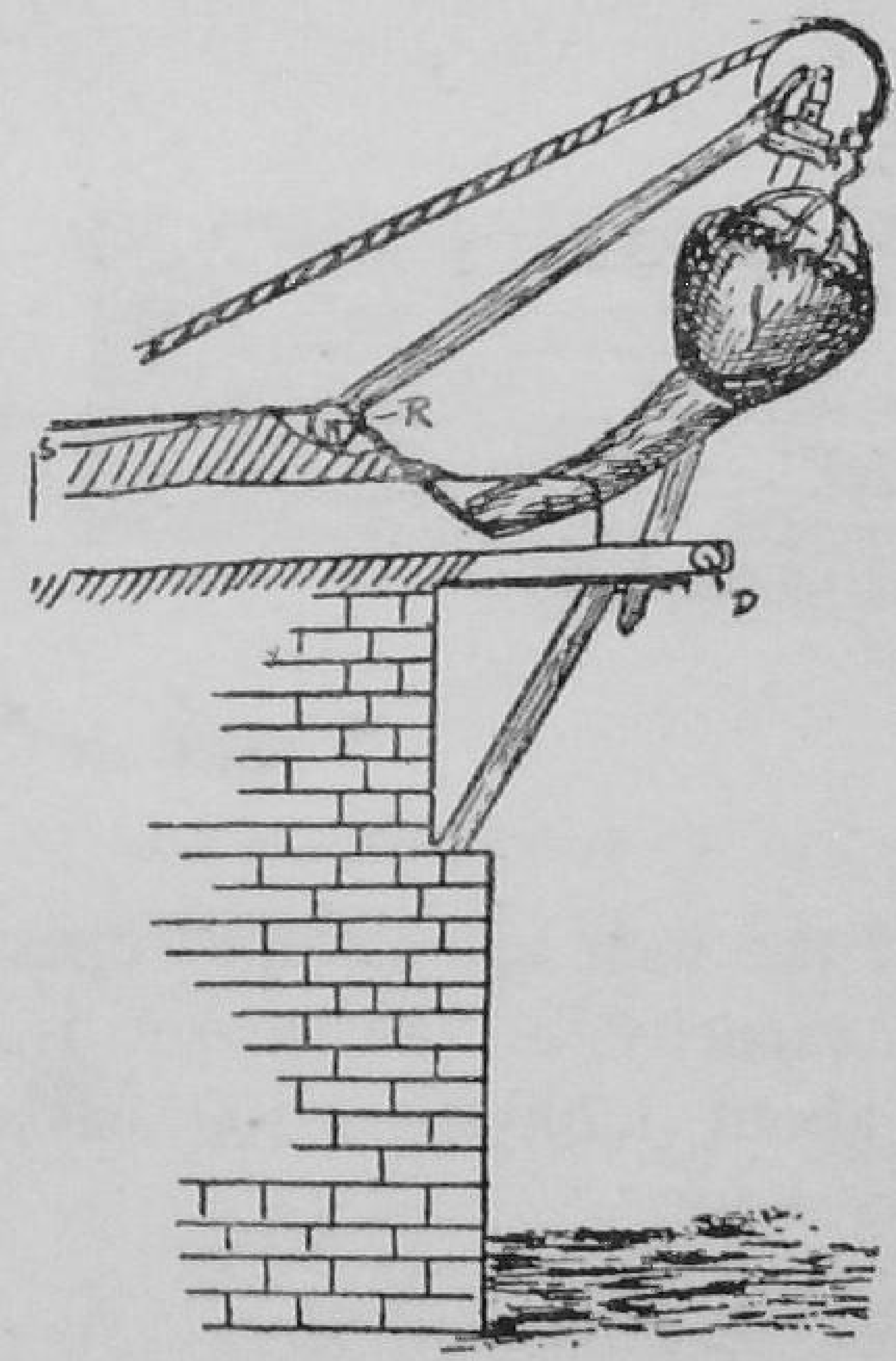

Fig. 5*a*. *Mhote* or *Kapile* showing the bucket discharging water through its tail.

(*After Wood*)

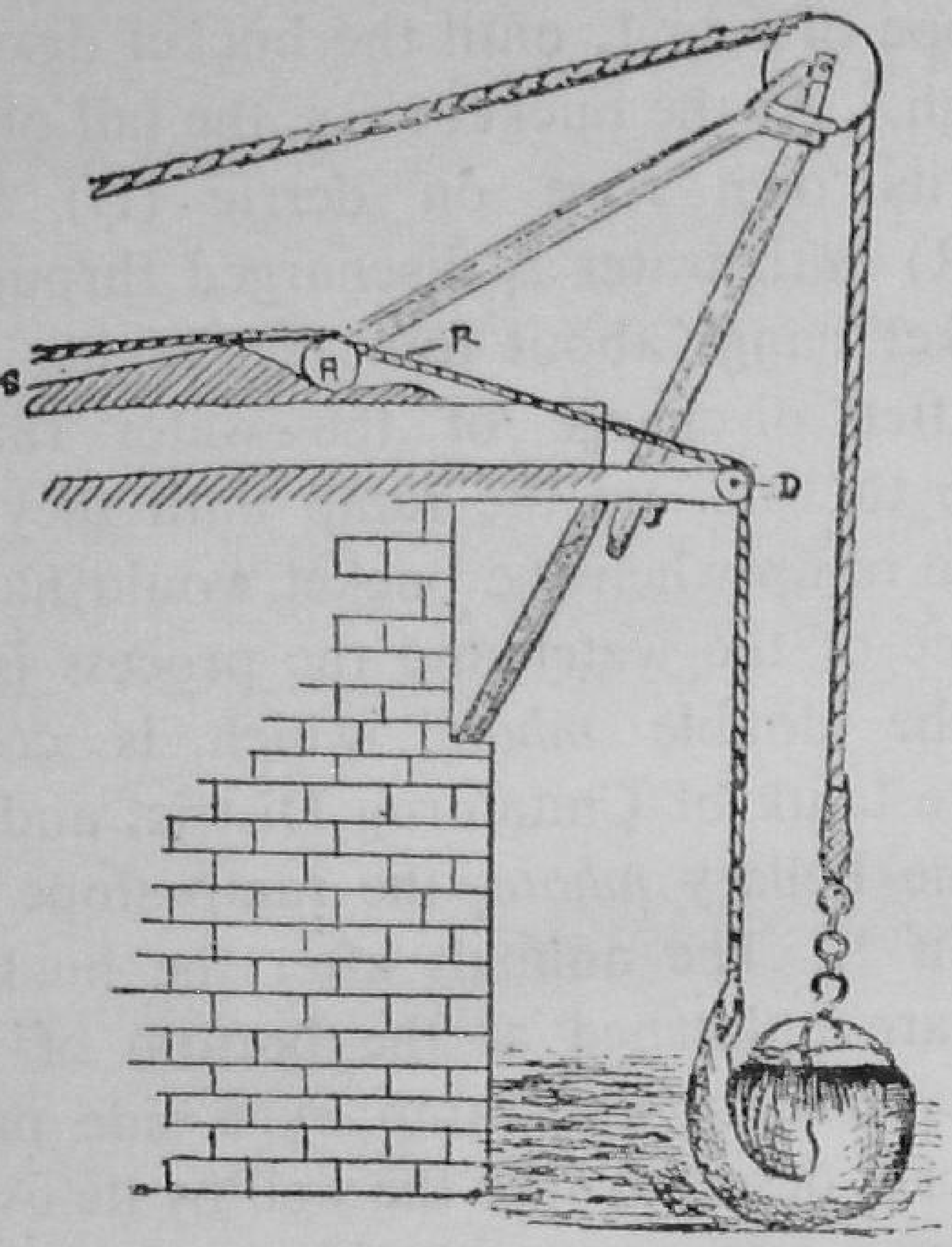

FIG. 5*b*. Above showing the bucket filled with water rising from water.

D. Derrick roller.
R. Ramp-roller
S. Slope of ramp down which the bullocks move.

most general in use. Here too, as in *piccota*, a portion of the weight of the bullocks working the *mhote* is used to raise water, which adds to the efficiency of the lift.

In the single type, the bullocks are made to raise the bucket by moving down the ramp, the length of which corresponds to the depth of the well, and which

has a slope of 5 in 1, until the bucket discharges into the trough. As the bucket rises, the tail of the bucket follows its own rope on derric (D) and ramp-rollers (R) until water is discharged through the tail. The bucket hangs about four feet higher by a thick rope. After discharge of the water the bullocks are made to back up the ramp until they reach the top of the ramp when the bucket would have reached the surface of the water and the process is repeated.

In the double *mhote*, which is common in Challakere taluk of Chitaldrug District and is known also as the Bellary *mhote*, the ramp slope is steeper being 3 in 1. The animals after the bucket is discharged, are unhitched at the bottom of the ramp and they return up the ramp by a side path. The empty bucket descends into the well by its own weight with the man returning with the rope to the top of the ramp, where he fastens the rope to the second pair of bullocks which is waiting. In experienced hands the bucket can be worked to discharge 40 to 60 times in an hour. The capacity of the bucket varies from 30 to 40 gallons, the double *mhote* having bigger buckets.

Improvements tried with these lifts have beer (1) providing valves, (2) providing tilting buckets, and (3) providing roller-bearings for pulleys and steel ropes in place of fibre ropes. None of these have come into general use as they mean increased cost or complication of an already simple system.

Circular Mhote

This consists of a circular drum round which the bucket-rope winds and unwinds. The bullocks walk round on a level. Hence unlike the ramp *mhote*, it is the strength of the bullocks that raises the bucket and the weight of the bullocks is not made use of. Buckets used are smaller and the output is less. This is seen round about Bangalore and seems to have been introduced from the neighbouring district of Chittoor, of Madras Presidency.

The Persian Wheel or Rahat (Fig. 6, *a* and *b*)

This is largely used in Central and Northern India. It consists of a large wooden drum built on a central axle, round which an endless rope runs to which earthen vessels are attached. The length of the rope is adjustable so as to dip in the water in the

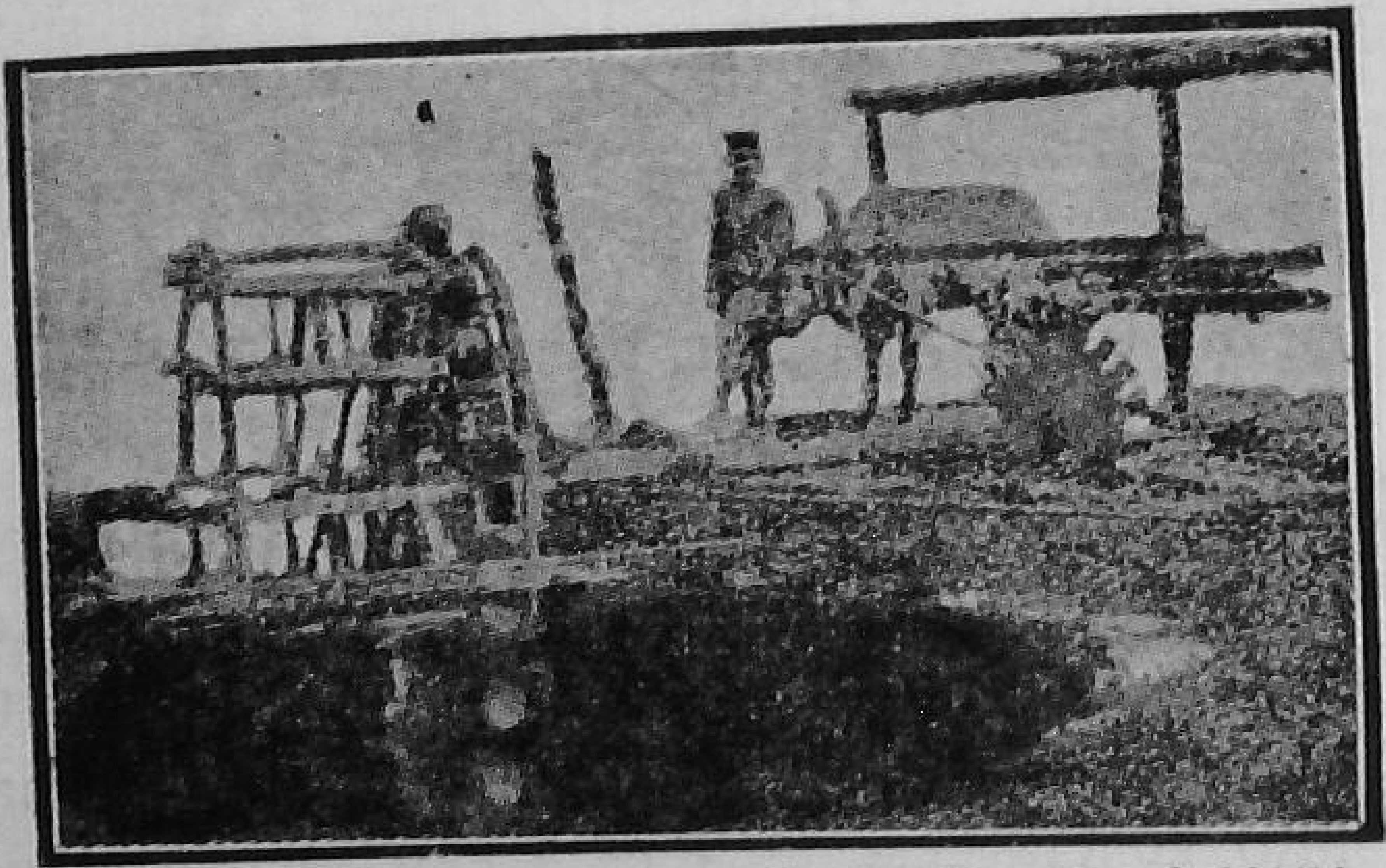

FIG. 6*a*. (After Bombay Agri. Leaflet 22 of 1927.) Local Wooden Persian Wheel with Earthen Pots on Rope.

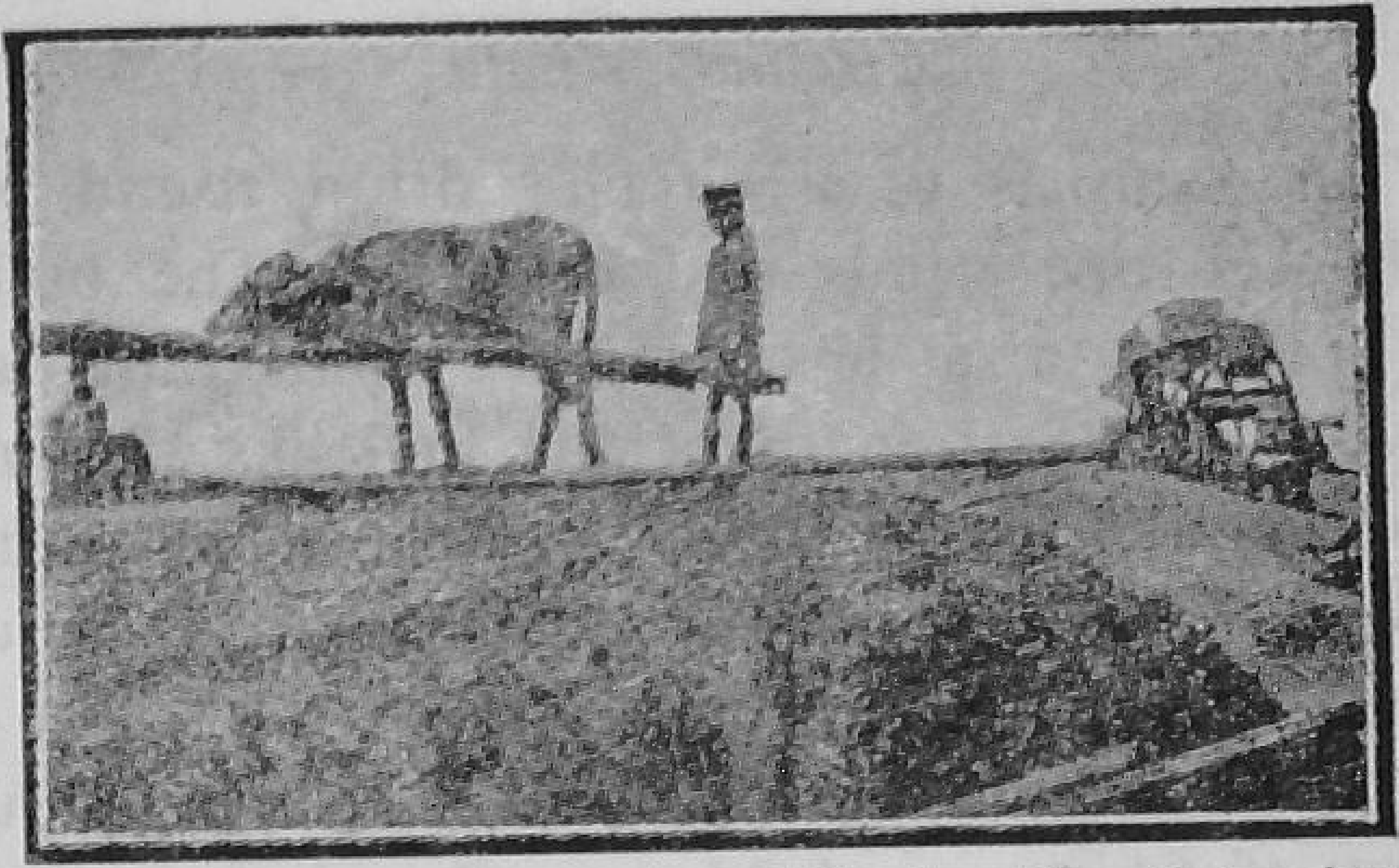

FIG. 6*b*. Improved Persian Wheel with Galvanised Iron Buckets and Gearing.

well. When the drum is rotated (this may either be done by manual labour or by bullock power by having a gear), the pots get filled in the well, move up with the rope on to the drum and discharge into the trough. It is a common sight in Central India to see these creaking huge wooden wheels. There are improved bullock-gear models of iron, with galvanised iron buckets which are more efficient and durable than the country ones. These lifts discharge about 3,000 to 8,000 gallons of water per hour with about 15 feet lift.

Chain-Pump

This works on the same principle as the persian wheel, except that the water instead of being lifted, is pulled up in a pipe by leather washers fixed on endless chain, which moves within the pipe. To avoid slipping of the chain grooves are cut in the wheel.

Wind-Mill or Aermotor

This is a contrivance by which wind is caught by the vanes of the aermotor which gives the necessary power to turn the mill. The turning shaft of the motor is coupled to the water-pump which lifts the water. As the wind velocity is not constant and at times and in seasons is not strong enough to work the mill this is not a dependable means of water-lift at all seasons.

Other water-lifts may be mentioned. Pumps for lifting water worked by oil-engines, gas-engines, or electricity as motive power are coming more and more into use. For us in Mysore, cheap electricity is replacing rapidly, round-about cities and towns, other sources of power for irrigation purposes.

The following table taken from Sir Alfred Chatterton's *Water-lifts* gives some important facts about water-lifts :—

Name of water-lift	Mean lift in feet	Duration in minutes	Gallons per hour	Efficiency percentage
Double Mhote, Saidapet ..	22·125	180	1,867	66·6
Stoney's improved	22·6	90	2,500	79
Subbarao's improved—				
Single Mhote	23	60	2,178	34
See-Saw	18	45	1,903	50
Sultan	21	60	2,570	70
Andrew's Persian Wheel ..	12	120	3,204	49·6
Single Mhote, Palladam ..	32	120	1,110	48
Single Mhote, Bellary ..	35	240	3,770	47·57
Piccota or *Yatha*	14·18	420	2,735	80

CHAPTER V

METHODS OF IRRIGATION

WATER having been brought to the land to be irrigated, there are several ways by which it can be applied to the land. These methods vary according to the topography or lay of the land, the soil and the crop it has to benefit. In practice, usually it is found that about 70% of the water-holding capacity of the soil is the optimum water content for the crop. For sugarcane it is about 85%. In irrigation one must aim at seeing that this quantity is given to get the best results. Evenness of distribution of water is of great importance. If there is twice the water in one place that there is in another, the soil dries unevenly. It is well to imitate nature as nearly as we can. To this end it is highly desirable to prepare the land so as to remove the inequalities in the surface of the field. This lessens work in irrigation, water is economised, and an even stand of crop is assured. A very convenient and cheap implement for this kind of work is the scraper. It is known also as slip or scoop scraper. It holds about 3 cubic feet of earth and is very well suited for small jobs (Fig. 7).

Flooding.—This word is loosely used when water is freely allowed to flow over the field to irrigate. In particular the term is used where water from a stream in flood is allowed to spread over the land so that it may drop the silt it carries, to enrich the soil.

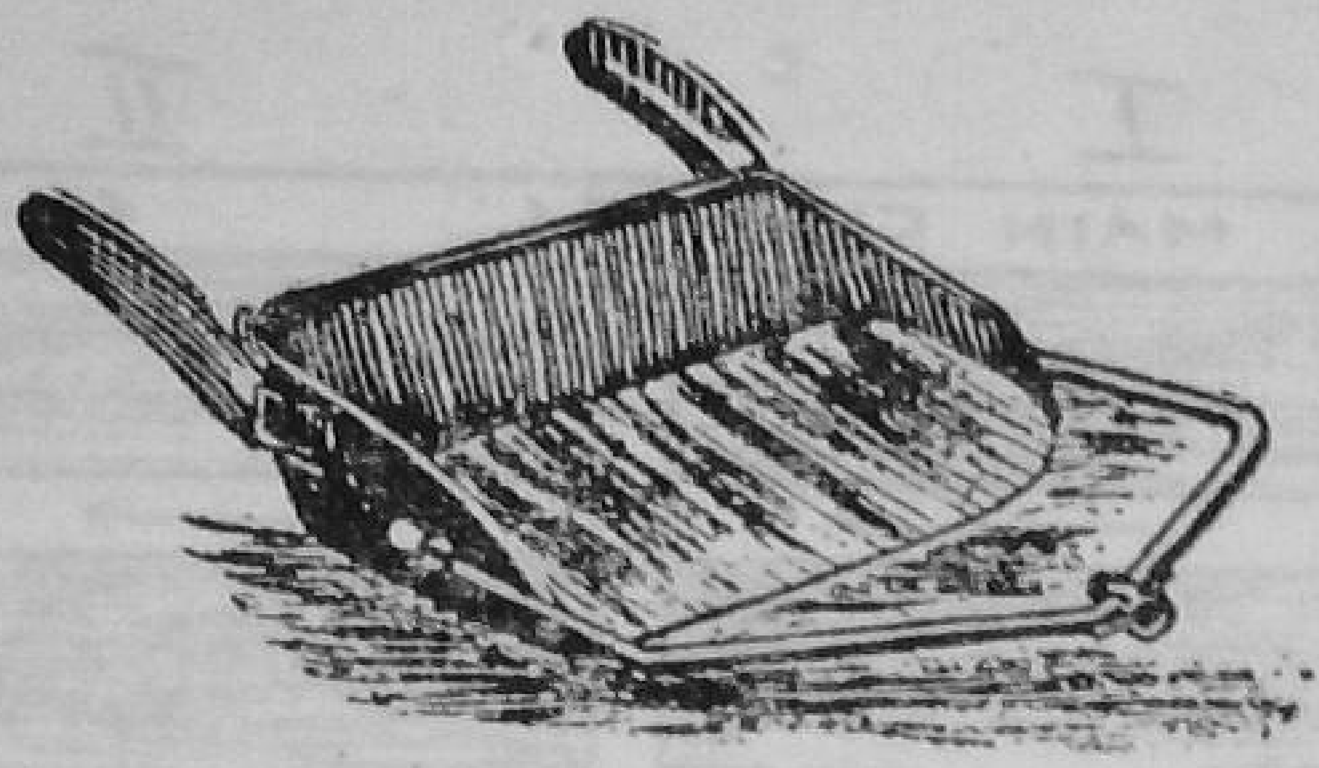

FIG. 7. Land leveller or Scoop scraper used for levelling uneven land. Bullock power is used.

The method is not a common one and when used for irrigating crops is highly wasteful of water.

Furrow Irrigation.—This method is employed for crops sown or planted in rows. The water is let into the furrow, which is short and on a dead level, and closed when full, allowing water to percolate slowly. This method is common for crops like chillies, onions, etc. If the furrows are long on a sloping land there is the danger of the velocity of running water causing erosion. One inch drop in 16 feet is considered safe and the longest length that can be recommended is from 100 to 125 feet, when furrows are deep and are properly maintained. Usually a working basis for all conditions would be about 25′ to 30′ (Fig. 8).

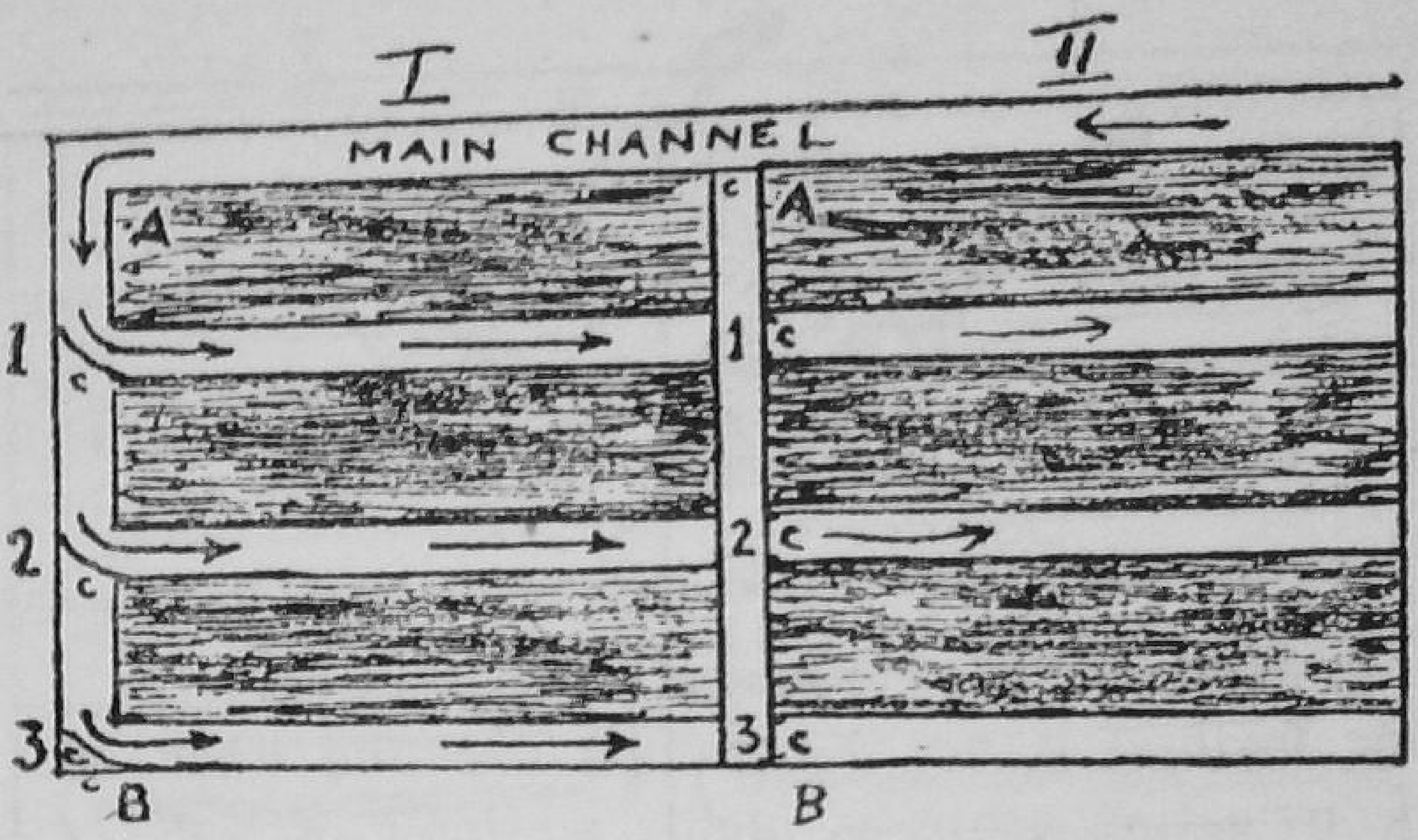

FIG. 8. Furrow Irrigation

I. Shows irrigation given from B to A. Please note the checks (C) put across the water course.

II. Shows irrigation given from A to B, which checks (C) closing against furrows.

Irrigation of plots alternately as in the sketch, *i.e.*, B to A, A to B, and so on is recommended, as it helps in controlling water better, and also facilitates inspection as one passes along the headlands.

An adaptation of furrow irrigation is to be seen in what is known as zig-zag irrigation (Fig. 9) for sugarcane in Chitaldrug District, which is extensively adopted in the new sugarcane area covering thousands of acres under Krishnaraja Sagara irrigation scheme. Ridging sugarcane heavily to suit this zig-zag system of irrigation is known locally as making *muri* (ಮುರಿ ಮಾಡೋದು), a term derived from and an abbreviation of original *nagara muri* (ನಾಗರಮುರಿ), an expression connoting the tortuous way a cobra takes in moving.

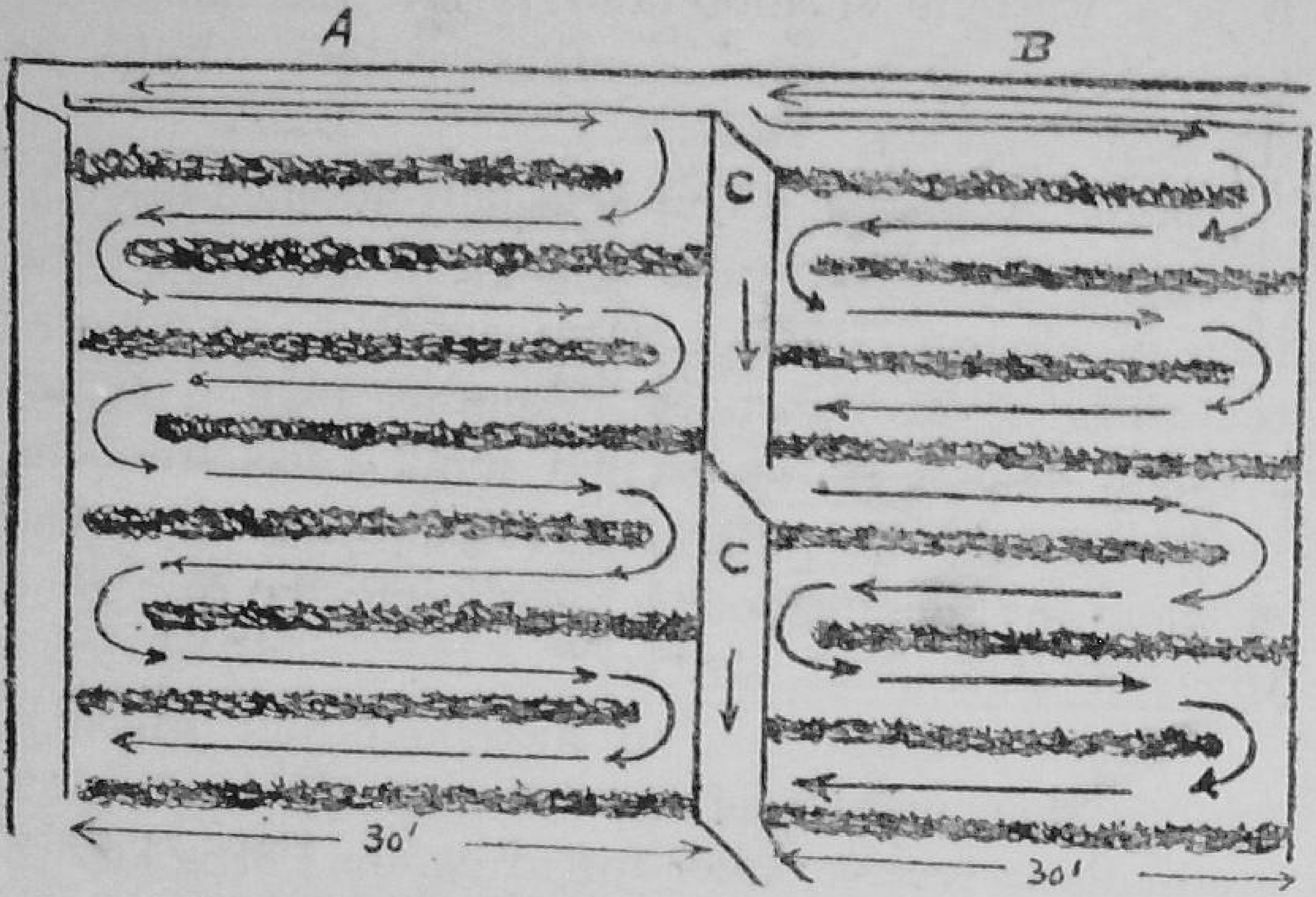

FIG. 9. Zig-Zag Irrigation

A. Shows wrong method. Here water, where the land is sloping, runs over double the proper distance of B. A wasteful and harmful method to be avoided.

B. Shows correct method. Checks (C) break the plot into proper units, where the irrigation water runs for 120 feet, the recommended distance; water being distributed more evenly.

On level lands it works satisfactorily as water stands on a level throughout the furrows in the plot and is most economical of labour. But the system is practised even on new lands which are not levelled and on slopes. The danger here is that the water is allowed at the top end of the plot to flow down the long slope carrying fertilisers and silt, and setting up erosion. Further there is an accumulation of water at lower levels, at the expense of top portions.

It is a wasteful method and is not recommended. Under such conditions contour system would be the best.

Basin Irrigation.—This is usually adopted in orchard irrigation. The water is allowed to stand round trees in a basin. For orchards, irrigation in concentric rings is recommended. Another plan is to set a length of pipe in the ground about 3 feet from the trunk into which water is poured until full. The water in the pipe percolates slowly into the root zone where it is required most.

Check Irrigation.—This method is one which is adopted on paddy fields, where small level plots are made to receive water for irrigation. It is known also as Checker-Board system.

Strip Irrigation or Border Method.—Long narrow strips of land are laid out for irrigation and water is allowed to enter at the highest point to spread over the land in a sheet. The slope of the land should not be much and should allow water to spread over the land without causing erosion (Fig. 10).

Surface-pipe Method.—This is not a common method. It consists in leading water of irrigation through detachable pipes running on the surface of ground which are detached as portions of land are irrigated.

Sub-irrigation.—Perforated pipes are laid under ground, not so deep as drain pipes but about 2–3 feet deep and about 10 to 12 feet apart. Water is

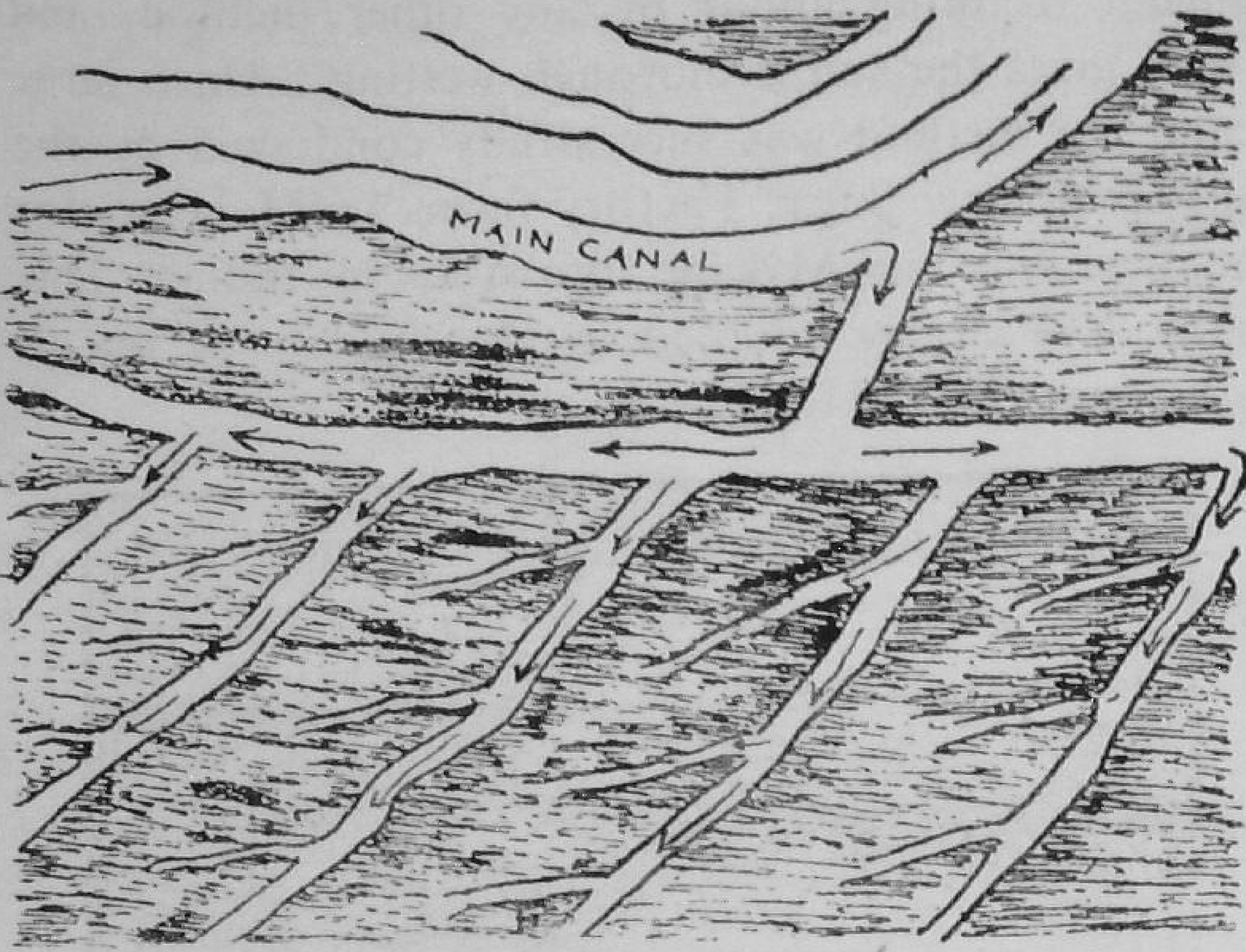

FIG. 10. Strip or border method of irrigation.

allowed into these from a source which has about 3 feet head, which is considered sufficient to allow water to occupy underground pipes, and irrigate the soil through the perforations.

Contour-irrigation.—This is irrigation according to levels. When new lands are brought under irrigation and levelling means great outlay which may not pay, this method is recommended. It is not possible to lay out these lines accurately unless with a levelling instrument, but once the contours are fixed, there would be nothing further to be done. This method gives best results on hill slopes and uneven lands as water stands in furrows at dead level: a factor,

difficult to bring about by any other method, and which gives the soil a thorough wetting. On a large scale, the method was successfully conducted by the author on new Sugar Factory farms in Mandya, for the first time in Mysore, probably in India. This method is largely adopted in Hawaii Islands on all hill slopes (Figs. 11, 12 *a*, *b*, *c*).

FIG. 11. Sketch showing contour irrigation on different slopes. Water courses are lines running down hill.

(*After Gilmore*)

There are three ways of running furrows on such lands:—

(1) With rows parallel to upper contour.
(2) With rows parallel to lower contour.
(3) With rows parallel to both contours.

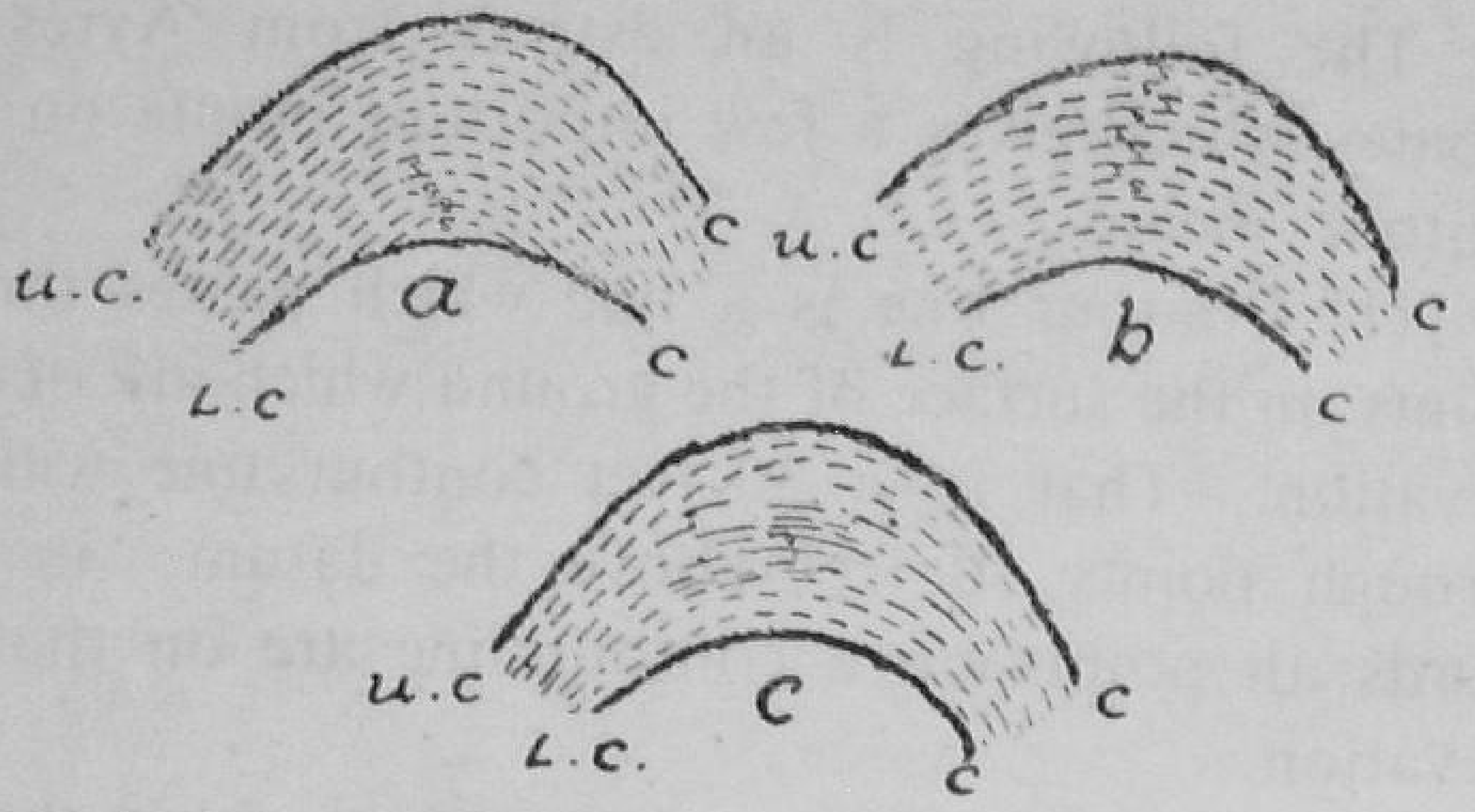

FIG. 12. *a*, *b* and *c*. Showing how contour furrows may be opened in three different ways.

a. Shows furrows opened parallel to upper contour.

b. Shows furrows opened parallel to lower contour.

c. Shows furrows parallel to both contours.

u.c., upper contour.

L.c., lower contour.

Continuous lines represent contour irrigation channels.

Dotted lines represent contour furrows across which will be water courses for furrow irrigation.

The most advantageous is the first method as the short rows are thrown against the lower contour which facilitates cultivation, as turning can be done on the head lands.

The second method throws the short furrows against the upper contour, hence it is not so advantageous in working.

The third method is very inconvenient as the short furrows come in the centre of the plot, which makes it difficult to irrigate and cultivate.

The following is an extract from Ayres and Scoates which gives a few important points on what contour means:—

(1) Contour line is a line which passes through points on the surface of the ground which are of equal elevation. That is, a 30 feet contour line will pass through points 30 feet above the datum; in other words all points on a contour line are on the same elevation.

(2) All contour lines close either within the confines of the map or outside. Where they close outside the boundaries of the map, they are stopped at the boundaries.

(3) All contours which close within the boundaries of the map show either a depression or a rise.

(4) Contour lines never cross each other except in case of a overhanging cliff.

(5) Contours equally spaced have a uniform slope.

(6) Contours in crossing a valley run up the valley on one side, cross the stream, and run back on the other side.

(7) The steepest slope is at right angles to the contours.

DRAINAGE

CHAPTER I

DEFINITION AND HISTORY OF DRAINAGE

DRAINAGE consists of the prevention wherever possible, of surplus water from getting on or into the soil, as well as removal from the surface and the interior of the soil, of the surplus water that cannot be intercepted. The object of drainage therefore is to control this surplus water in order to render the soil more suitable for cultivation, to prevent erosion and to provide more healthful soil conditions.

HISTORY OF DRAINAGE

The history of land drainage can be traced as far back as 400 B.C. The Greek Historian Heredotus speaks of its application to the Nile Valley, in dealing with the civilisation of Egyptians. As a means of land reclamation it was practised in England in the Fen country, in eastern England. The area thus reclaimed was 680,000 acres. In Holland a huge drainage scheme has reclaimed a lake known as Harlem lake, which was 14½ miles long, 8 miles wide and containing 13 feet of water. 44,000 acres have been secured for cultivation of crops and over 16,000 families have been settled on the area. In Italy large littoral tracts have been reclaimed for cultivation purposes by state drainage schemes and a large farming population settled thereon.

Necessity for any such schemes in India has not arisen as arable land is available in plenty. It is estimated that for the whole of India there are 170 million acres of cultivable waste lands still available.

The subject with which we are directly concerned is the direct drainage, which the individual cultivator is to execute, to drain his own land of surplus water.

The first step towards drainage is to get the area surveyed to determine the actual size and shape of field or farm and the topography of the land to show contours. Contours are drawn from one foot to 30 or 40 or even 100 feet in hilly lands. On a flat, one foot contours would be sufficient.

Nature of Soil in Drainage

The kind of drains, the intervals at which they have to be put and other details have to be determined according to the nature of the soil. The reaction to drainage varies with the mechanical composition of the soil, that is the size and gradation of the individual particles of the soil (texture). Popularly this is classified under sand, loam, clay, etc. Since, in nature, soil contains a variable mixture of soil-separates, analysis is done by the sieve method. In addition to the above, all soils contain a certain proportion of jelly-like substance consisting of sub-microscopic particles called "colloids". This is known also as the clay-complex. The exact function of colloids in soils as to its influence on the behaviour of the soil is not fully understood, and is under investigation.

CHAPTER II

KINDS OF DRAINAGE

THERE are in the main two kinds of drainage, *viz.*:—

(1) Surface drainage and

(2) Sub-surface drainage.

Surface drainage consists of the prevention of surplus water from getting on to the surface of the soil, as well as removal of all surplus water off the soil. This is done by various methods consisting of contour terracing, contour ploughing with proper dead furrows to act as small drains, levies, open drains, etc.

Before considering what system of drainage would be necessary, it would be well to know the quantity and source of water that requires to be removed. It is usually the rainfall that is not absorbed by the soil, and runs over the surface that proves to be destructive to agricultural land. This water is known as the " run off " and is defined as " that portion of the rainfall that is not absorbed by the soil, is not utilised by vegetation or lost by evaporation and which finds its way into streams as surface flow ". This surface surplus water may also be due to wasteful use of irrigation water, that would render lands useless which would otherwise be useful for agricultural purposes.

Usually open drains are opened for draining such water. Scientifically the size of the drains is fixed in relation to quantity of " run-off " which varies

with rainfall, soil, topography, vegetation, shape and size of water-shed, etc. This requires the working out of "discharge coefficient" of the area. This is the amount of water which runs off from a given area in 24 hours. In practice however, open drains are laid on an assumed discharge coefficient, with side slopes to suit the soil to prevent caving and blocking the drains and with proper ground slope for free flow of water. Such a drain may be widened, and deepened, if found inadequate.

Side slopes of a drain are the slopes that its sides make with the horizontal. If the sides are vertical in an average soil, the sides will cave in. The slope is expressed in number of feet of the bank in the horizontal direction to one foot of the vertical. For example, a slope of 3 in 1 would mean for every 3 feet of run of the horizontal the bank would rise

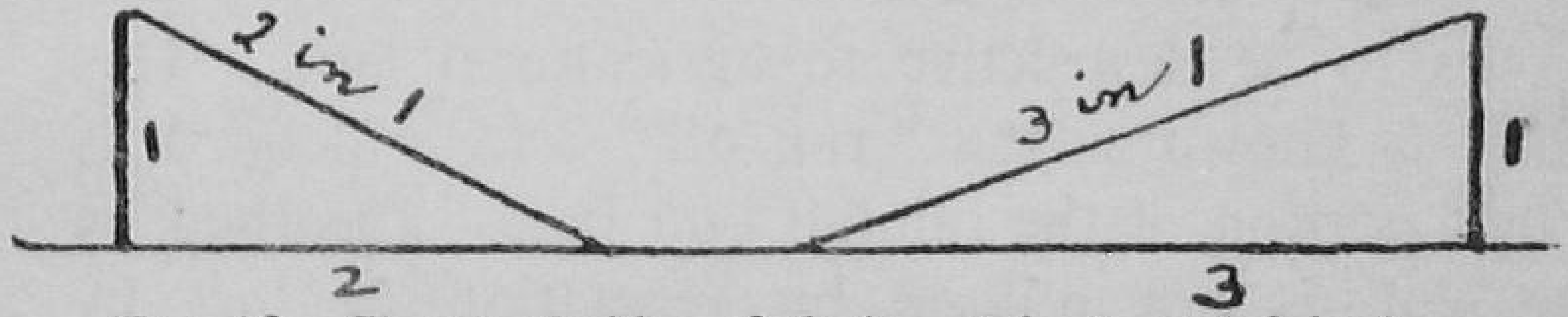

FIG. 13. Slopes of sides of drain, 2 in 1, and 3 in 1

vertically one foot (Fig. 13). In expressing slope the American Convention of the Horizontal to raise Ratio is adopted in this work throughout instead of the usual convention of the Ratio between the Rise to Horizontal distance. The following slopes are recommended for different soils:—

Soil	Slopes
Loose rock	½ : 1
Clay	1 : 1
Sandy loam	2 : 1
Very sandy soil	3 : 1

In regard to velocity for open drains it differs again in different soils and the ideal ditch is one which is so designed that it cleans itself, without eroding the sides or bottom. The maximum velocity for sandy soil is 1½ to 2 feet per second, for loam 3 feet, and for stiff clay 4 to 5 feet. Roughly 2–3 feet per second is recommended.

It should be emphasised here that the drains must be clear of obstacles and cleaned every season, so as to allow free flow of water so that they may function efficiently.

Sub-surface Drainage.—There is a popular belief among cultivators that surface drains should be enough to drain water-logged soils. This is true to a certain extent especially when there are drains close enough and the subsoil within 3 to 5 feet of the surface is sandy or gravelly, which acts as an efficient medium through which surplus water is got rid off. Usually drainage problems arise in clayey soils where sides of open drains cave in or get puddled by the action of water, thus sealing them from water seepage. "V"-shaped drains about 30 feet apart will benefit the land, but these can function for a very limited period and require to be opened out for each crop, which adds to cost. As a permanent method this has to be given up.

Pole-drains (Fig. 14).—This is a cheap method where jungle wood is available. Drains may be opened out 2½ to 3 feet deep and one foot wide. The

poles are arranged in the shape of a triangle and the ditches are filled in. The excess water of the soil would seep in around the poles and flow along the pole-drain into the main drain. As wood should be easy to get on a farm this method is cheap, but as with the decaying of wood the soil fills in the drain-space it gets choked after a time and does not function efficiently. It is a temporary method.

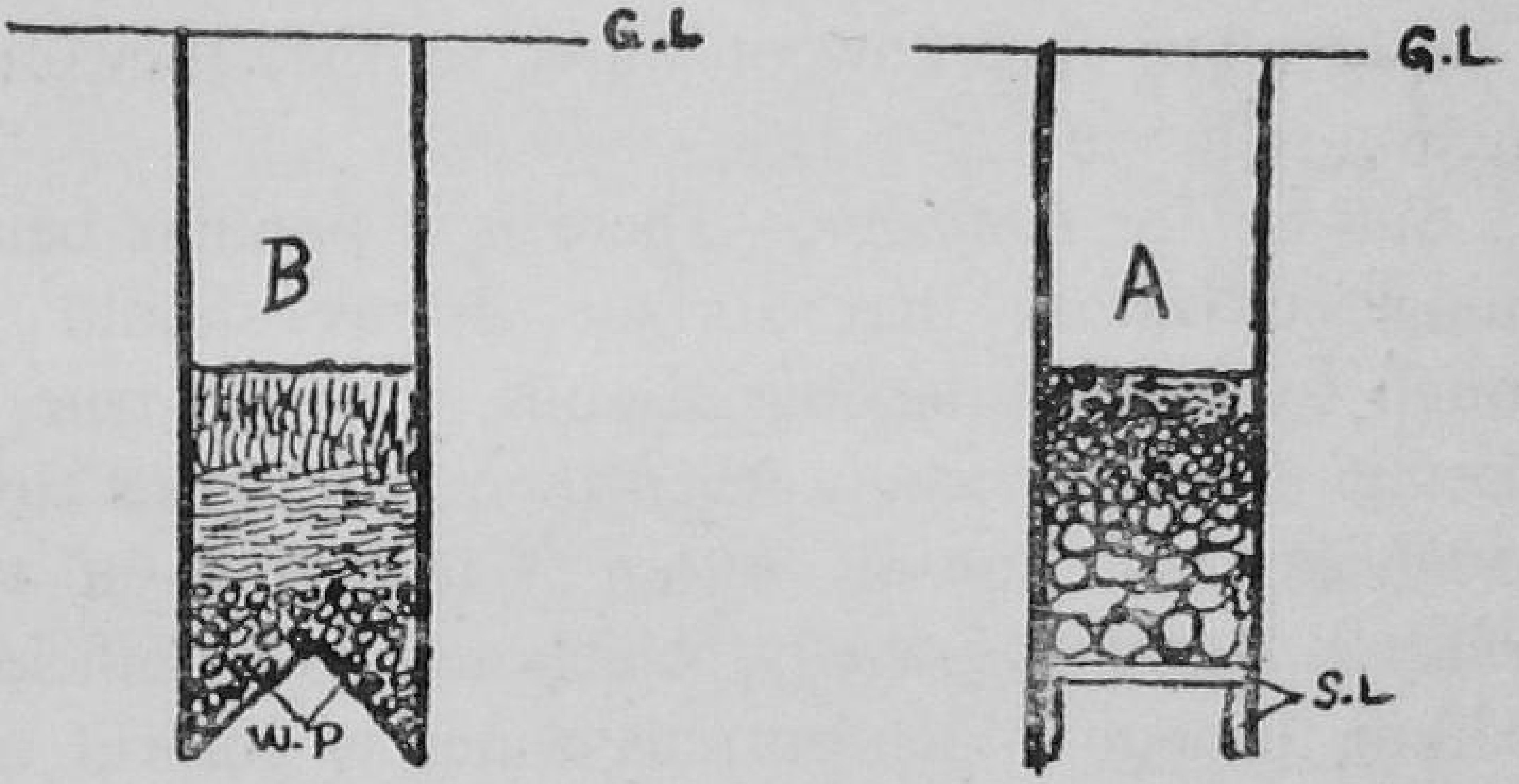

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FIG. 14. Pole-drain

W.P. Stout poles arranged like a triangle, over which are placed thick sticks. Above this is the brush wood and soil on top.

FIG. 15. Stone-drain

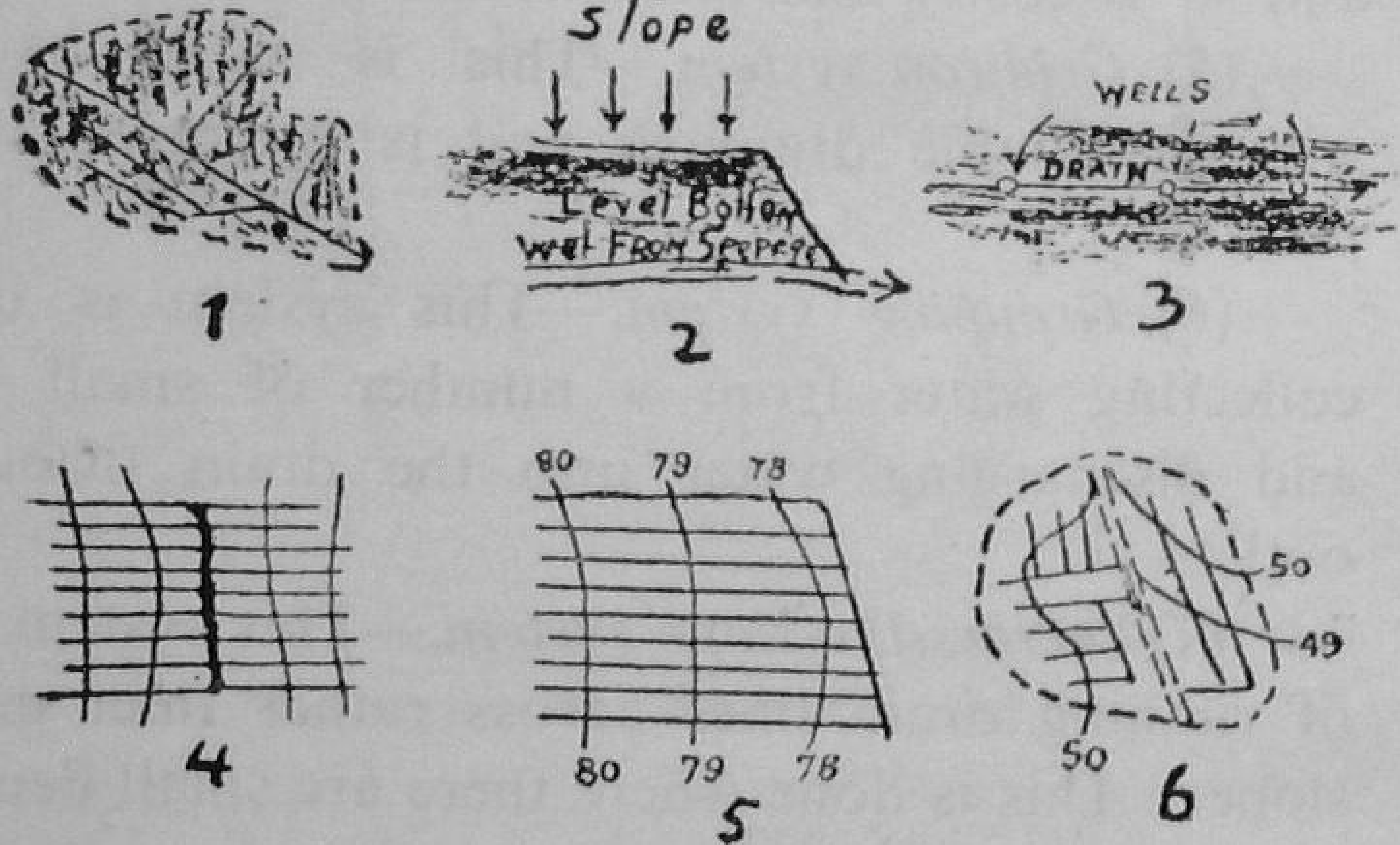
S.L. Stone slabs arranged to form a channel below. Above this are large stones. Small diameter ones are filled in above this and on top, soil.

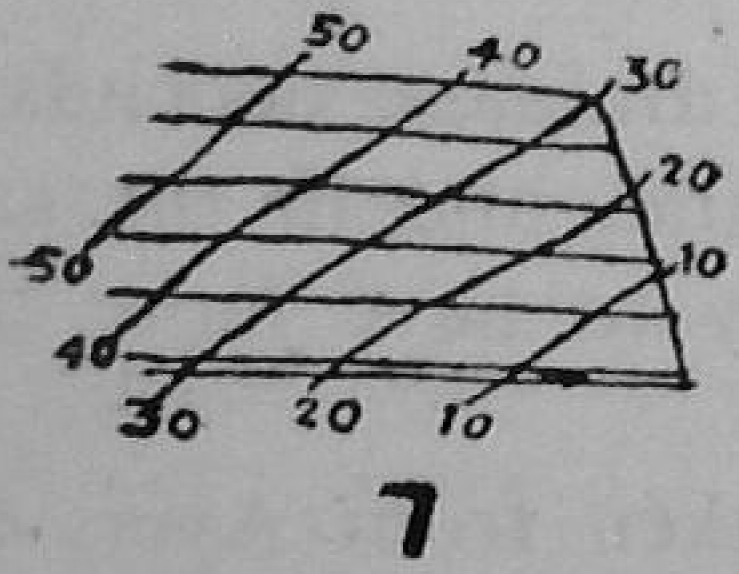
Stone-drains (Fig. 15).—Stones may be used, same as poles. Large flat stones may be used for the sides of the drain, with one over the top, to form a small channel. Big stones of nine inches diameter

and above may be filled in leaving space in between, and smaller stones of 6″ may be used on top, covering the drain with soil. Even here after a few years, silt gets into the spaces and clogs the soil.

Tile-drains.—The most efficient and permanent method is the tile-drain, but it is very costly and requires skilled labour and accurate lay-out. It is doubtful if with cheap labour and for growing ordinary crops it would be economical.

The following are some of the important recognised systems of tile-drains :—





1. Natural system.
2. Cut-off system.
3. Elkington system.
4. Herring-bone system.
5. Gridiron system.
6. Grouping system.
7. Across-the-slope system.

FIG. 16. Important types of tile-drains (*After Ayers and Scoates*).

(1) *Natural system.*—This is done to drain out certain local wet spots in the land.

(2) *Cut-off system.*—This system is used on seepy hill-sides where water makes the bottoms wet and unproductive.

(3) *Elkington system.*—Practically it is the same as 2 but wells are dug in at intervals so that water accumulates in the well, rises to the level of the drain and flows through the drain tiles.

(4) *Herring-bone system.*—This is used on a flat with two sloping sides and involves double drainage and so is costly and uneconomical.

(5) *Gridiron system.*—This is same as 4 but without double drainage and is preferred wherever possible.

(6) *Grouping system.*—This system is used for collecting water from a number of small systems, and discharging water into the drain through one outlet.

(7) *Across-the-slope system.*—This system consists of running drain lines across rather than down the slope. This is done where there are small depressions in the drain-lines on contours.

Selection of the system of drainage depends on the condition and lay of the land, and in the same land it may be found necessary to have more than one system.

The following principles taken from Ayers and Scoates will help in laying out drains:—

(1) The mains should be put along the natural drainage lines. This is obvious as water runs that way.

(2) Mains and laterals should be, as far as possible, placed in straight lines. When the directions have to be changed, it should be done by easy long curves. This is important as by changing the direction of the flow, velocity is lowered and sediment is dropped, thus choking the drain. It is desirable to cut small banks to keep drainage lines straight.

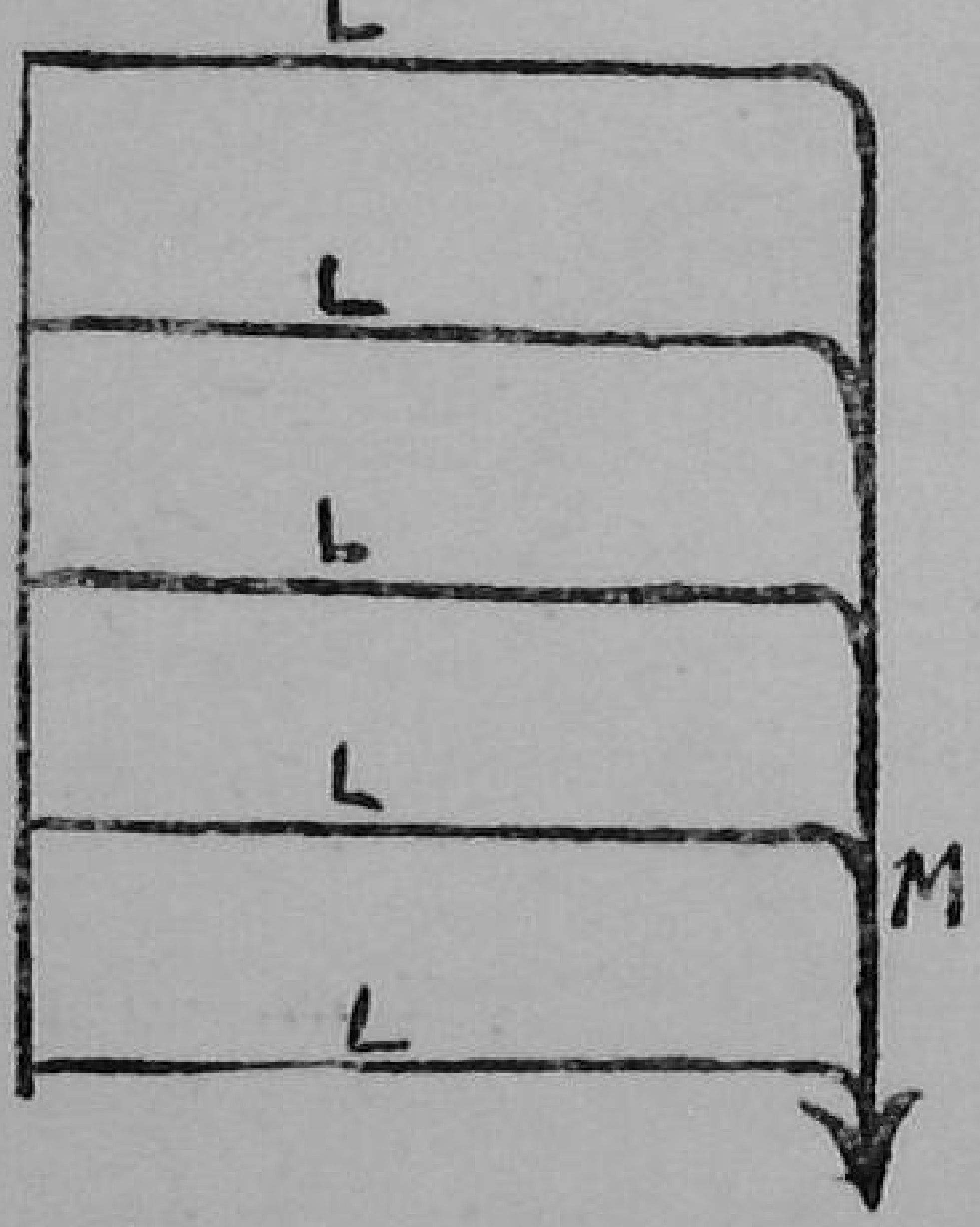


FIG. 17. Shows curves at the joining of the lateral drain with the main drain to prevent silting at the connections.

(3) Laterals should be given the greatest fall possible.

(4) Laterals should be in long lengths in order to eliminate double drain.

(5) The system should be selected so that all the land may be drained equally.

(6) The number of outlets used should be held to a minimum.

Main drain is one into which several lateral drains and sub-mains empty their water.

Sub-main is a short main, receiving water from laterals and which empties into the main.

A lateral is a drain which collects water from the soil and empties it into the sub-main or main.

CHAPTER III

BENEFITS OF SUB-SURFACE DRAINAGE

SUB-SURFACE drainage results in lowering the surplus or gravitational water-level from two to four feet below the surface of the ground. As the water percolates down, air is drawn into the soil to take its place. This is known as soil aeration. Drainage has the following beneficial effects on the soil:—

(1) It results in warmer soil. Waterlogged soils are slow to warm up as water takes more heat to raise temperature by 1 degree than the same volume of air. Therefore when there is air in the soil, it warms up much quicker and maintains a higher average temperature. This allows earlier planting of crops and lengthens the growing season.

(2) It gives the root zone greater depth, which increases the available supply of plant food and moisture. Under favourable conditions roots of field crops are seen to go down to 3 to 4 feet.

(3) The physical condition of the soil is improved. Wet soils, especially clays, are hard to handle if soil puddling is not avoided. Drainage permits the development of granular or crumb structure so necessary to good tilth and lengthens the period during which optimum soil moisture content prevails. Drained land is more safely and easily worked, lightening the effort of farm operations.

(4) The aeration and higher temperature due to drainage increases the activity of the soil organisms by whose efforts the plant food of the soil becomes available.

(5) By improved physical condition of the soil it retains a larger quantity of film-water, which in dry periods becomes useful to plants.

(6) It improves the sanitary condition of the soil reducing toxic substances in the soil.

It must be borne in mind that surface drainage is as important and unless this is attended to first, sub-surface drainage becomes inefficient.

CHAPTER IV

ALKALI (*REH* OR *CHOULU*) SOILS AND DRAINAGE

WHILE on the subject of drainage, it would be necessary to refer as to how drainage helps in preventing lands getting alkaline, or in cases of lands which are already alkaline, how drainage reclaims the land from alkalinity.

Under exceptional conditions of prolonged drought, in humid climates or conditions, there occurs an accumulation of soluble mineral substances at or near the surface of the soil. This phenomenon is known as alkali, *reh* or *choulu*. Chemical processes which bring about this may be briefly explained here. Alkali is sometimes a single salt, but generally is a mixture of two or more of the chlorides, sulphates, carbonates, bicarbonates and occasionally nitrates, phosphates, borates of sodium, potassium and calcium. When the carbonate of sodium is present to an appreciable extent the salt mixture is known as " Black alkali " in contradiction to " white alkali ", which does not usually contain sodium carbonate. Black alkali is so called because the solution containing sodium carbonate, in rising to the surface of the soil, dissolves and carries with it organic matter which is subsequently left on the surface of the soil in more or less blackish deposits, often ring-like in appearance. It is not uncommon

to find black deposits which may not contain black alkali, and white alkali which contains sodium carbonate.

In the field, alkali is found in a number of forms and its chemistry can be known from the soil-solution reactions. Whatever the origin, its segregation at or near the surface of the soil is everywhere much the same. Precipitation of the solutes may take place at the surface, more commonly a few inches below, owing to the fact that under conditions of rapid evaporation, there is ordinarily a discontinuance in the capillary columns, or the film-water at a point below the surface of the soil, the water diffusing thence into the surface as the vapour phase.

In the majority of cases the predominating compound is sodium chloride from which locally salt is extracted and these are known as *Uppina-mole* (ಉಪ್ಪಿನ ಮೋಳೆ). When calcium carbonate is an important compound of the soil, as hard-pan or otherwise, sodium carbonate or black alkali is also present or apt to appear when the land is brought under irrigation. When calcium sulphate or gypsum is present, there is less probability of black alkali appearing, and when gypsum predominates or calcium carbonate is present in very small quantities, black alkali is generally absent or sodium sulphate is an important constituent of the alkali.

It is the effect of alkali on the physical aspect of the soil we are here concerned with. The calcium

carbonate and calcium sulphate have a cementing action or hard-pan formation. Black alkali by dissolving and segregating the organic matter at the surface removes from the lower soil layers the humus compounds, which are of great value in maintaining soil structure favourable to plant growth. "Black alkali" is one of the best deflocculating agents, so that soils with this, puddle readily and are reclaimed with the greatest difficulty.

In reclaiming alkaline lands much importance is given to growing alkali-resistant plants like the Australian salt bush. We have crops like ragi, paddy, cocoanut, dhaincha which are resistant to a slight extent. Application of calcium sulphate or gypsum is a method recommended. Increasing the humus content of the soil by growing green manure crops resistant to alkali like Dhaincha, wild indigo, *Crotalaria striata*, etc., and incorporating them into the soil regularly year after year, in addition to applying large quantities of farm-yard manure, forms an important part of reclamation of such soils. The best use of alkali lands involves irrigation. Sandy soils for instance are the easiest to get rid of alkali as there is natural drainage and the salts can be easily washed down. In heavy soils the only procedure to combat it, as a permanent system, no matter what the texture, is the installation of efficient sub-surface drains. This process is necessarily slow but once attained can readily be maintained.

Salt content of a soil is expressed as a percentage of the total weight of soil. Alkalinity is expressed in a notation. *p*H 7 means that the soil is neutral, *i.e.*, neither acid nor alkaline and anything above that (*i.e.*, *p*H 8 and onward) is alkaline. Below *p*H 7, it is acid.

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